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Terrestrial observation

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TERRESTRIAL OBSERVATION

15

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Fort Sill, Oklahoma,
November, 1918.

TERRESTRIAL OBSERVATION.

Document No. 46b. (16a and 46a, revised)

GENERAL PRINCIPLES AND DEFINITIONS.

Terrestrial observation of artillery fire may be divided into the following general classes:

Axial.
Lateral.
Flank.
Combined.
Bilateral.

The following discussions are intended to assist in understanding and applying the methods of conducting fire for adjustment and effect of field artillery. They are not intended to take the place either of the Provisional Drill Regulations for Field Artillery, 1916, or of Artillery Firing, Army War College, 1918. They are supplementary to and explanatory of both of these, though more especially of that part of Artillery Firing (Part V) which relates to the adjustment of precision fire for demolition, the conduct of a percussion bracket adjustment, and fire for neutralization as prescribed by French regulations.

Adjusting Point.

If the target has any breadth, one part of it must be taken as the adjusting point, from which the displacement of the rounds to the right or left is to be measured. The adjusting point should fulfill the following conditions:

Be sharply defined.
Be plainly visible.
Be a part of the target and, if possible, at the center.
From its nature, allow an easy adjustment.

Observing Line.

The line running from the station of the observer to the adjusting point is called the observing line.

Sensing of "Target".

A round is sensed as "target" only when definite effect is observed on the target.

If, during adjustment, a round is observed to strike the target, the deflection is considered adjusted.

Precautions Taken to Assist Observation.

The firing of each round of each salvo should be announced to the observer so as to prevent unnecessary fatigue and to permit him, by know-

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ing the time of flight, to distinguish his rounds from those of neighboring batteries.

In firing by salvos the rounds are fired in the order of the pieces, at intervals convenient to the observer, beginning with the leeward piece, so that the smoke from one round does not hinder the observation of the following rounds.

In percussion firing, the bursts should be to the windward rather than to the leeward side of the target in order that the smoke may blow across the observing line.

Sensings should be made promptly.

AXIAL OBSERVATION.

Axial observation occurs where a station is approximately on the line battery-target; that is, where the observer displacement does not exceed one hundred mils. In such a case, if the observation station is near the battery, the observed errors in deflection are sent to the gun without change.

When the distance observer-target is less than the distance battery-target, the observed errors in deflection must be reduced to their value at the guns, and vice versa. This reduction is accomplished by multiplying the observed errors by the ratio, distance observer-target divided by the distance battery-target.

GENERAL DUTIES OF BATTERY COMMANDER IN CONDUCTING FIRE.

As a rule the battery commander takes a position from which he can see the target. If there is no post fulfillling this condition he goes wherever his presence is most needed, ordinarily to his command post.

In any case the battery commander must consider the condition of the personnel and the difficulties of fire in deciding whether it is advisable for him to personally conduct the fire from the O. P. or to remain at the battery. In the former case he leaves the battery in charge of the executive and in the latter he carefully designates the target to the observer, (if possible from the O. P. itself) informing him precisely as to the conditions of observation and giving all orders necessary to obtain the desired results.

Functions of Observer.

An observer senses and reports the position of rounds falling as seen by him, not attempting to translate this into the actual position of the bursts with relation to the line gun-target. The latter is the function of the battery commander.

The object of all observation is to enable the battery commander, by using the reports given to him by the observer, to make such deflection or range changes or both, as will finally enable him to get an adjusted elevation and a deflection such that the center of impact of rounds fired at that elevation and deflection will be at the target. The order and methods of making these different changes for the various classes of observation are set forth hereafter.

Fire is usually divided into two general classes, (1) Fire for adjustment and (2) Fire for effect. There is no sharp line between fire for adjustment and fire for effect. Some, and often a great deal of effect is obtained during adjustment. Thruout fire for effect, the fall of the shots is observed whenever possible with a view to still further improving the adjustment.

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FIRE FOR ADJUSTMENT.

General Remarks. The degree of precision desirable in adjustment depends on the fire to be executed as a result of this adjustment; consequently, it varies with the nature of the target and the tactical situation.

If quick action is required against an enemy with little or no cover, only an approximate adjustment is made. If on the other hand, it is necessary to demolish strong works, the adjustment must be accurate.

Adjustment in Deflection.

Before opening fire, the battery commander determines one or more points (adjusting points) upon which he wishes to see the projectiles fall. Against narrow targets, or wide ones presenting only a narrow surface that is clearly defined, all pieces are adjusted with respect to the same point. Against wide targets, fire is adjusted in deflection so as to cover the entire target.

The battery commander choses a reference point for deflection close to the target (if not on the target itself), and a reference point for height of burst if using time fire.

Avoid the command "As you were", which confuses the personnel. This command is strictly prohibited in the field artillery. If the battery commander has been mistaken and has given the command "Left 10" when he should have given "Right 10", he must let it stand and order twice the correction in the opposite direction; that is, "Right 20."

When the error does not exceed three mils, the deflection is corrected only if several successive errors in the same direction render it advisable, or if a shift to the other side of the adjusting point would improve the possibilities of observation. After several rounds have been observed, however, in fire demanding very great precision, it may be corrected if the error exceeds 1 mil.

When the first shot cannot be sensed for range, bold deflection changes should be made to obtain a sensing on the observing line in axial observation. (Methods for lateral observation explained below).

Adjustment in Range.

General Remarks. In precision fire, adjustment in range is generally made with percussion fire.

Fire for adjustment should be conducted rather rapidly, in order that atmospheric conditions may not have time to change, and thus the last rounds may be comparable to the first. Furthermore, it is always well to obtain effective fire as soon as possible.

It is better to adjust by piece. After adjustment with one piece is complete, each of the others verifies the quadrant elevation obtained, taking account at the same time of its own errors and of the correction for adjustment already found. The method of doing this is set forth in detail hereafter in this pamphlet.

On a moving, unsheltered target, however, fire must be executed with all the pieces.

Conduct of Fire during Adjustment.

In discussing the conduct of fire, the term "fork" is frequently used. It means the change in elevation equal to four field probable errors or six theoretical probable errors. In the 155mm and 75mm range tables the word

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"fork" should be substituted for the word "bracket". A bracket is entirely different: it is the term applied to the difference in elevation or range expressed in yards, meters, degrees and minutes, or 20ths, between two elevations or ranges which have given bursts respectively over and short of the target. Deflection bracket, simularly, is the difference in deflection (expressed in mils) between two deflections which have given bursts respectively on one side and the other of the target.

Fire for adjustment includes two phases:

Approximate adjustment, or "Trial fire."

Close adjustment or "Fire for improvement".

Trial Fire.

This consists in obtaining a certain elevation or range known as the "trial elevation." at which a series of rounds is to be fired "for improvement" as hereinafter explained.

This trial elevation is obtained as follows:

A verified bracket, including the target, of a depth usually of one fork in the case of the first piece of the battery to be adjusted, is sought.

When an adjusted elevation as described hereafter has been obtained on the first piece, the method of obtaining the trial elevation on the second and succeeding pieces varies, depending on whether or not the guns are calibrated.

If the guns are calibrated, two rounds should be fired by the second and succeeding pieces at the adjusted elevation (described hereafter) of the first piece. If the two rounds give an over and a short, improvement fire with that piece is begun immediately, that elevation being taken as the trial elevation for that piece. If the two rounds are both in the same sense, the trial elevation is sought in the usual way, bounds of one fork are taken, and two rounds are fired at each elevation to save time.

If the guns are not calibrated, ordinarly trial fire should be started at the adjusted elevation of the first piece and bounds of one fork should be used. Two rounds are fired at once on bringing in the 2nd piece.

If the apparent over and short limits of such a bracket have been obtained on the sensing of only one round at each limit, it is necessary to verify those limits. This is done by firing the second round at each of those bracket limits, unless a long time has elapsed since the first round was fired, or there have been sudden atmospheric changes. In either of these cases two more rounds are fired and observed at each limit, and the sensings of the original rounds are disregarded.

If, from this fire, we get both of the shots fired at the long limit of the bracket over and both fired at the short limit short, the two elevations or ranges are said to be "verified." The mid range of the bracket thus obtained is then taken as the "trial elevation".

If, however, in the course of verifying the limits of the bracket as above, we get an over and a short at any one elevation or range, this is said in the French Drill Regulations to constitute a "contradiction," that is, the range is said to be "bracketing". Two more rounds are then fired at the same elevation. If an over and a short are again obtained, this elevation is taken as the trial elevation, and no further verification need be made. In trial fire a target shot is considered as one "over" and one "short" and is treated as a contradiction .

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If, however, the second two rounds are in the same sense, the first two rounds fired at the range are entirely disregarded and the second two are taken as verifying the long or short limit of the bracket sought, as the case may be. The contradiction is in this case is said to be "cleared." The other limit of the bracket must then be verified as above, if such verification has not already been obtained.

Fire for Improvement.

Just as soon as a trial elevation, as above described, has been obtained in either of the two ways stated, fire for improvement is begun, wherever time and the nature of the target permits. The object of this is to adjust the center of impact as closely as possible to the target. Under the French drill regulations this is done by firing usually twelve rounds per piece in series of six rounds, the first series being fired at the trial elevation. In lateral observation, when the deflection has not been satisfactorily adjusted, the series consists of 3 rounds each.

Where the first series of six rounds fired at the trial elevation, gives opposite sensings, the second series is fired at the same elevation. When all rounds of the first series are observed in the same sense, however, the second series is fired at an elevation one half a fork greater or less than the trial elevation, depending on whether the sense of the first series was short or over. The total number of rounds thus observed is considered to have been fired at the mean of the two quadrant elevations or ranges employed. Note that it is necessary to have twelve observations, not merely rounds fired. If rounds are lost or cannot be observed for range, others must be fired to obtain the necessary number of observations. As a rule, only rounds fired after improvement fire has begun should be counted in any such series. Rounds fired during trial fire should ordinarily be disregarded, unless they are fired at the same elevation or range as improvement fire, and the fire is continuous at the range, i. e. no shots fired at another elevation have intervened between trial fire and improvement fire.

After obtaining the series of twelve observed rounds fired as above the numbers of overs and shorts are compared. If they are equal, this range or elevation is taken as that at which fire for effect is to be opened. This is called the "adjusted elevation." If they are not equal note how many rounds must be changed in sense in order to make them equal. This number divided by the total number of observed rounds in the series gives the fraction of the fork by which the range or elevation must be changed in the appropriate sense to bring the center of impact on the target. For example, twelve rounds are observed, eight are over and four short. In order to make the overs and shorts equal, two rounds would have to be changed from over to short. The elevation or range would therefore have to be reduced by two twelfths or one sixth of a fork. A special case occurs where one or more "target" shots are observed during improvement fire. In this case each target shot is counted as one over and one short, each "over" as two "overs", and each "short" as two "shorts". The trial elevation is then changed by the necessary number of twenty-fourths of a fork. For example if 8 "overs", 3 "shorts" and 1 "target" were observed, they would be considered as 17 "overs" and 7 "shorts", and the elevation reduced by five twenty-fourths of a fork. The elevation so obtained would then be taken as the elevation at which to open fire for effect.

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In the fire for improvement, if the first series of six rounds is in the same sense and after the elevation is changed in the appropriate direction by half a fork, the second series of six rounds is also in the same sense as the first one, fire for improvement is temporarily abondoned, and trial fire is again undertaken. Bounds of one fork will be used in taking up the trial fire again in such a case, and 2 rounds will be fired.

In the case of fire observed from one lateral observation post, it is generally necessary to precede the "fire for adjustment" by "preparation fire", hereafter described, in order to get a round on the line observer-target.

Remarks.

This method of adjustment takes no account of the magnitude of the errors. There should, therefore, be no toleration of the tendency displayed by beginners to assume that a round is only slightly short or over and to fail to verify the long and short limits, or to consider themselves justified in not firing the second verifying round. This always delays adjustment, and often renders it inaccurate by reason of the errors of observation arising from a preconceived idea.

In adjustment, never try to gain time by deviation from the precise rules given by the regulations. These rules are the fruit of many years' experience of certain results, and a misinterpretation of them always leads to a waste of ammunition.

When fire is reopened, having been previously adjusted under certain atmospheric conditions, and every time the powder lot is changed in course of fire, the elevation is verified, i. e., trial fire is resorted to no matter to what stage the previous adjustment had progressed.

When, in the course of fire, the type of projectile is changed, the corrections to be made to the elevation and the deflection are determined in accordance with the range tables and the elevation is verified.

For United States Matériel, the ranges are given in yards, and the fork is generally taken as one hundred yards. The smallest change that can be made on the range scale being twenty five yards, minor changes may be made only to the nearest 25 yards. With these exceptions the same rules for adjustment are applicable to our matériel.

Fire for Effect.

Before opening fire for effect the battery commander warns the observer, if he is not observing himself.

In order to be certain in the use of the results of adjustment, fire for effect should immediately follow fire for adjustment.

The sheaf is opened or closed by the proper amount, if this has not already been done.

Fire for effect is of two types:

(1) Precision fire for demolition, when observation is continuous.

(2) Zone fire, when observation is not continuous, or lacking entirely.

Precision Fire for Demolition.

The adjusted elevation or range for each piece having been determined by fire for adjustment, as previously described herein a series of 6 or 12 salvos is fired by the battery as a whole.

This method of fire is to permit the observer to sense and record separately each round from each piece, when this can be done, and the time

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interval should be ordered accordingly. After the series is finished, the totals of overs and shorts are reported to the battery commander.

Based on this report, corrections are made if necessary, to obtain an equal number of shorts and overs, taking the battery as a whole. Corrections for individual pieces are made only when the number of shots observed for any piece is at least equal to the number observed for that particular piece during improvement fire. Thus, if in a series of twenty four rounds fired by the battery, the six rounds fired by one piece are all observed over or short, an individual change would not be justified in that piece. It must be made only after at least six more observations for that particular piece. If any piece cannot be corrected, it ceases firing, and fire for effect is continued with the rest of the battery.

While battery salvos are occasionally used, usually fire for effect for demolition on a small target is carried out by piece or by platoon salvo. The general principles above set forth as to the number of rounds to be fired and the number of sensings justifying a change in elevation, would govern.

The ammunition used would ordinarily be long shells in the 155mm in fire for demolition. The kind of fuse to be used would depend on the character of the target to be demolished.

Zone Fire for Effect.

This may be divided into two classes:

(a) Ordinary zone fire, where there has been some preliminary adjustment by means of trial fire, use of reference target, etc.

(b) Zone fire where preliminary adjustment has been impossible, called "systematic fire", and usually fired from the map only. This kind of fire is used to a very large extent in actual warfare.

Ordinary Zone Fire.

Where observation of the fire on a target is impossible, or where lack of time prevents improvement fire, zone fire must be resorted to. It consists in covering by fire a certain area in which the target must lie. The dimensions of any given zone depend on the size of the target and the supposed accuracy of the preparation of the data.

The Depth of Zone:

The depth to be taken in different cases is as follows:

After a percussion bracket adjustment where observation is possible but where there has been no time for improvement fire, the depth of the whole bracket should be fired through. Both limits of the bracket should be verified except in lateral observation. In this case the adjustment is by a single piece, and it is not considered necessary to verify limits on account of lack of time. The bracket should be from one to four forks deep, depending upon the character and mobility of the target. Fire is delivered with the 155 mm. howitzers at 50m. bounds; with the 75 mm. gun, bounds are 25 m. for shell. The ammunition to be used would either be "D" shells with long instantaneous fuses or, if the target should consist of troops or artillery on the march, time fire shells or shrapnel may be used. If shrapnel is used, bounds of approximately 100 meters should be taken for both 155 mm. howitzer and 75 mm. gun.

After transfer of fire accurately made from an auxiliary target or a reference target, a bracket of one fork should be assumed. The limits

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of such a bracket should lie at distances one-half fork short of the corrected range and one-half fork over. "D" shell with long instantaneous fuses should ordinarily be used in firing through such a bracket, though, if the target justifies it, time shells or shrapnel might be used. The range changes set forth above for the various kinds of ammunition would apply to fire in such a bracket.

In certain cases, the slope of the ground must be taken into consideration in firing through the bracket and the bounds above set forth for the different kinds of ammunition would have to be changed in order that the area included in the bracket might be covered effectively. This is covered in "Artillery Firing" and F. A. D. and S. R.)

When it is possible to observe, as in the case of a percussion bracket adjustment, the observer watches results and sends them in for the whole series of rounds fired at its completion, giving merely the total shorts and overs observed and not usually attempting to keep records of each piece.

The Width of Zone.

In the first case stated above, that of a percussion bracket adjustment made when there is no time for improvement fire, the width of the zone should be at least equal to the width of the target. In the second case, after a transfer of fire, the width of the zone should be the width of the target plus eight mils on each side of it. The front effectively covered by each 155 mm. shell is 20 m. and for a 75 mm. shell 12 to 15 m. (2 shells for each 25 m). If, therefore, the front of the target does not exceed fifteen or twenty meters for each piece (depending on the caliber) to be used in firing on it, each piece is laid on the center of its appropriate part of the target. If the front exceeds fifteen or twenty meters per piece each piece is laid on the right element of its portion. One shot is fired at this deflection and appropriate sweeps or deflection changes are then made to enable the piece to cover its front of the target effectively, one shot being fired after each deflection change. (In time fire two shots are fired after each deflection change). The elevation is then increased or decreased by the appropriate amount called for by the zone being fired upon, and the ammunition used, and the process is repeated, until the whole zone has been fired through.

If it is desired that the distribution in the zone be not uniform, a schedule in writing should be given to each chief of section, showing the elevation and deflection of each of the various rounds to be fired in the order desired.

Systematic Fire.

The elevation for the objective is that corresponding to the map range, corrected for the conditions of the moment as far as these are known. The deflection for the objective is similiarly obtained. The depth and width of the zone to be covered vary with the supposed accuracy of determination of the firing data. The depth should be not less than two forks.

The foregoing discussion, altho specially applicable to axial observation, is given for all classes of observation; lateral, bilateral and combined. Except where specific differences are stated hereafter, the methods and principles above stated should be followed in all kinds of observation.

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LATERAL OBSERVATION.

Adjustment by means of lateral observation is employed when the observer displacement is between 100 and 1300 mils. This method is used extensively on account of the difficulty of finding observation stations which permit axial observation.

There are three distinct periods in the adjustment, as follows:

Preparation fire—which consists of bringing a round on the observing line and is executed in series or two rounds each.

Trial fire—which consists of bracketing the target in elevation and deflection by keeping the center of impact of the rounds on the observing line, and is executed in series of two rounds each.

Improvement fire—Which is executed in a series of 12 rounds fired at the mid-deflection and mid-elevation brackets to secure the adjusted deflection and elevation.

The rules of observation and interpretations, given below, should be thoroughly understood.

Every burst is observed with respect to the observing line, and the deviation in mils from that line must be carefully measured and noted. For example in Figure 1, the burst *K* is 10 mils left of the observing line.

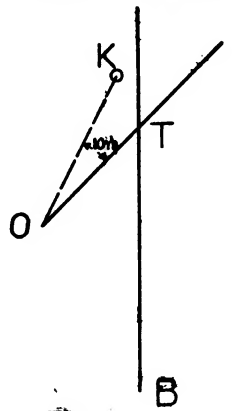

Fig. 1.

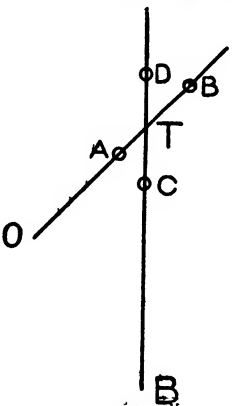

Fig. 2.

Every burst on the observing line is certainly short and the plane of fire is certainly to the left, if, with the observer on the left, the burst occurs between the observer and the target. For example, see *A* in Figure 2. Similarly, the burst is certainly over and the plane of fire is certainly to the right, if the burst appears beyond the target as, for example, *B* in Figure 2.

When it is certain that the plane of fire passes through the target (target hit), every burst to the right is certainly short and every one to the left, certainly over. For example, see *C* and *D* in Figure 2.

When it is certain that the plane of fire passes;

(a) to the left of the target and a burst appears to the right of the observing line; it is certainly short, as, for example, *J* in Figure 3. But a burst *J'* is doubtful as to range.

(b) to the right of the target and a burst apears to the left of the observing line, it is certainly over, as, for example, *K* in Figure 3. But a burst appearing to the right as at *K'* is doubtful as to range.

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Observing Sector.

Where a target has breadth as viewed from the observation station, the area between straight lines drawn from the observer to the right and left extremities of the target and prolonged for an indefinite distance beyond is called the observing sector. This area, of course, includes the observing line. If a round falls in this area on the observing line, it should be reported by the observer as "line short" or "line over". If a round is observed in this area but not on the observing line, it should be reported as "(so much) right", or (so much) left", indicating the number of mils that the center of the burst appears to the right or left of the adjusting point, and, if possible, in addition it should be reported as "over" or "short".

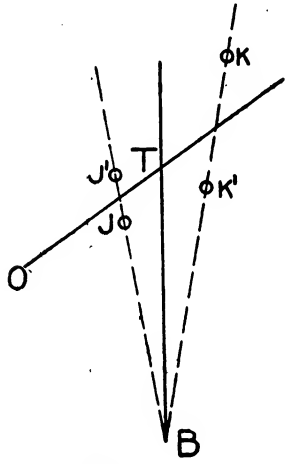

Fig. 3.

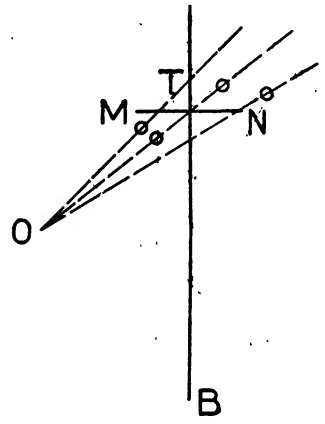

Fig. 4.

For example, in Figure 4, suppose *MN* to be the target and *T* the adjusting point. Every burst sensed left of the observing line and short, or on that line and short, is a positive indication that the plane of fire passes to the left of the adjusting point. Also, every burst sensed right and over, or on line and over, is a positive indication that the plane of fire passes to the right of the adjusting point.

Where a round is observed as falling outside the observing sector, its displacement to the right or left of the adjusting point only should be reported. Sensings of shorts or overs in such cases should not usually be attempted except in axial observation. During preparation or trial fire the observer will sense bursts as "so much right or left" of the observing line. If he can tell that the shots are short or over for range, he will announce "short" or "over" and if he can also tell that the plane of fire passes between him and the target, or the reverse, he will announce "deflection short" or "deflection over" as the case may be. Thus in a case where the observer is on the right of the line of fire, and the ground appears to slope up to the target as seen from the observing station and a round is observed ten mils left of the observing line; if it can be clearly sensed on the terrain as short for range

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and it can also be plainly seen that the plane of fire passes between him and the target, the observer would announce "ten left, short, deflection short".[1]

During improvement fire and percussion fire for effect, the battery commander will no longer sense shots which fall outside the observing sector as "so much right or left", but will sense them "short" or "over" depending on the location of the observing station and the side of the line on which the shots fall. Thus, observer on left of gun-target line, in improvement fire or precision fire for effect, all shots seen by him to right of *OT* line are short for range, those left are over. An observer, who is not the battery commander, will, however in all cases report rounds as actually seen by him, leaving it to the B. C. to translate rights and lefts into overs and shorts, as stated above.

This sensing by the B. C. of rights and lefts as overs and shorts in improvement fire and fire for effect is based on the asumption that the plane of fire is (by that time) thru the target. This may not be exactly true, but it is assumed to be true for all practical purposes when a lateral bracket of 16*m* or less has been obtained and subsequently halved. Even then great care must be taken in making sensings. For example: In the case as above observer on left when, according to this rule, rights are taken as shorts, if a shot is seen to the right, but smoke is thrown across the observing sector by the blast and seen over, the round is over and is also a positive indication for a deflection change.

In the case of shell fire, especial care should be taken in sensing shorts and overs. In many cases a dark colored target is apparently obliterated by a shell bursting immediately behind it, as the outlines of the target are momentarily obscured by the background of dark shell smoke. In some cases such rounds must be sensed as "doubtful". In others, by close observation, a movement or change of color may be noticed in the smoke background immediately following the burst and this will serve to bring out the outline of the target. In some cases where the terrain actually or apparently slopes upward as seen from the observing station, and a clear view of it is possible, the bottom of the shell burst may be compared with the bottom of the target. If the bottom of the shell burst is lower, the round is short; if higher, the round is over.

In all these rules, it has been assumed that the observer is on the left of the line gun-target. In case the observer is on the right of that line, the words right and left should be interchanged throughout.

No amount of rules can benefit any conductor of fire unless he has formed an accurate mental picture of the situation. This picture must be kept in mind continuously, so that every burst can be immediately interpreted.

---

[1] During the first week of lateral firing (actually on the range) the instructor will call attention to obvious terrain sensings and explain how they can be utilized and reported. Students may use them themselves, if they are perfectly obvious, but will not be penalized for failure to use them in their first week.

After the first week of lateral firing, students will be required to take advantage of obvious terrain sensings without aid from the instructor. In blackboard and terrain board work, terrain sensings will in no case be used, and shots must be in the observing sector to be sensed for deflection.

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PRINCIPLES OF ADJUSTMENT.

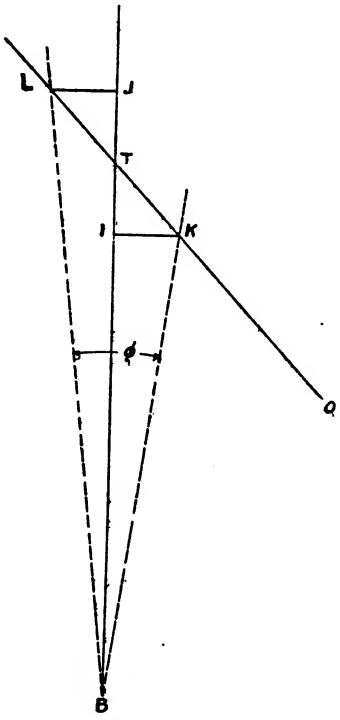

Figure 5.

When the battery commander has a battle map.

When the battery commander possesses an accurate map on which can be plotted the positions of the battery, of the target and of the observing station, the correction coefficient may be readily obtained with great accuracy by plotting the above positions on the plane table.

The Lateral Fork.

After the positions of the battery, the target and the observing station have been accurately plotted, the lines *BT* and *OT* should be drawn as shown in Figure 5. Along the line *BT* lay off the distances *TI* and *TJ* each equal to one half fork (50 yards with American matèriel). From *I* and *J*, draw arcs with ranges *BI* and *BJ*, centers at *B*, intersecting *OT* at *K* and *L*. These arcs may be assumed equal to *IK* and *JL*, perpendiculars to *BT*. Draw the lines *BL* and *BK*. Let the angle *LBK* equal ϕ. From the figure it will be seen that ϕ represents the deflection change that will be necessary in order that a burst may be moved up by one fork in range from *K* to *L* and still be kept on the observing line. The angle ϕ therefore represents the lateral fork which corresponds to the range bracket of one fork, and may be measured with a protractor. If the scale of the map is too small to plot these values conveniently the range fork should be laid out 2 or 5 times its value. The angles ϕ and ω will then be 2 or 5 times their true value, and can be reduced accordingly. For ω see below.

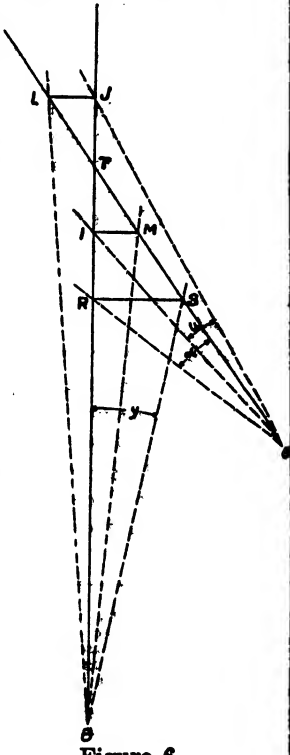

Figure 6.

The Correction Coefficient.

This may be defined as the amount by which the displacement from the observing line of the mean of two rounds fired at the same elevation, is to be multiplied, in order to obtain the change in deflection or range, as the case may be, to be given to the gun, to bring a round on the observing line.

(1) *When the round is to be brought to the line by a deflection change.* (*See "Open Warfare"*).

The lateral fork has already been plotted and measured. The lines *OJ* and *OI* (see figure 6) should be drawn on the plot-

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ting board. The angle at which the length of one fork in range is seen from O on the gun-target line is $IOJ=\omega$. The correction coefficient is then the ratio $\frac{\phi}{\omega}$.

Assume that a round falls at R. To get a round on the observing line by a deflection change, the plane of fire must be shifted to the right by the angle $SBR=\gamma$. This shift from R to S, as seen from O, is equal to the angle $ROS=\alpha$.

Assume now that a round has fallen at I. To get a round on the observing line by a deflection change, the plane of fire in this case must be shifted to the right by the angle $IBM=\frac{1}{2}\phi$. The shift will appear at O as $\frac{1}{2}\omega$.

Thus we have very nearly the following proportion:

$$\frac{\frac{1}{2}\phi}{\frac{1}{2}\omega} = \frac{\gamma}{\alpha} \text{ or } \frac{\phi}{\omega} = \frac{\gamma}{\alpha}.$$

From this we get $\gamma = \alpha \times \frac{\phi}{\omega}$.

Therefore we see that if, at the observation station, we measure the displacement of a shot from the observing line as α the deflection shift, γ, to be given to the guns is α multiplied by $\frac{\phi}{\omega}$.

This is the coefficient by which to get on the line by deflection changes.

Using a map, if the 1st burst center is farther away from the OT line than ω mils, bring the next to within ω mils by a range change. Then proceed as usual with deflection changes.

(2) *When the round is to be brought to the line by a range change.* (*See "Open Warfare"*).

Plot on the plotting board as before, the positions of the gun, the target and the observing station (see Figure 7.) Draw the lines BT and OT, lay off on the line BT a distance IJ equal to one fork with the center of the fork at T. Draw the lines IO and JO. Let the angle IOJ equal ω. Let the distance $IJ=F$. The correction coefficient in this case would be the ratio $\frac{F}{\omega}$. The value of F may be taken in any unit of range such as yards, meters or in degrees and minutes. ω is of course in mils. The result obtained by multiplying the observed displacement by this coefficient will be in the same unit of range as that in which F was originally taken. This is the range change, or elevation change, necessary to put a center observed ω mils off the line, on the line $RR'=\alpha \times \frac{F}{\omega}$.

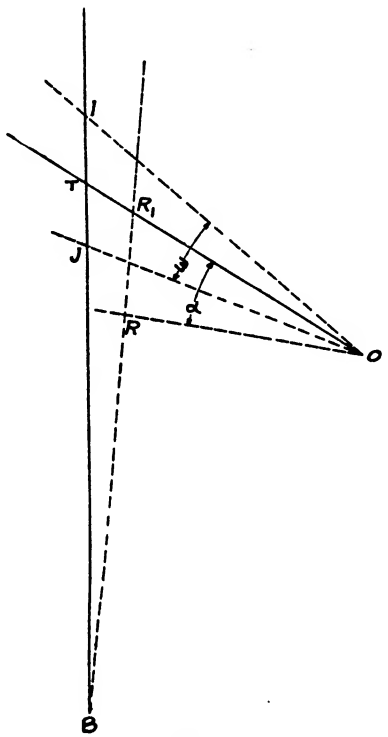

Figure 7.

This formula is derived as follows: Suppose a shot falls at R (see Figure 7. Draw the line BR and

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continue it past the line *OT*. Draw the line *RO*. To bring the shot to the observing line it is necessary to lengthen the range by the distance RR_1.

In the triangle ROR_1 the angle α in mils equals $RR_1 \div \frac{OR}{1000}$ multiplied by some obliquity factor which we may call *f*. Therefore we have

$$\alpha = \frac{RR_1}{\frac{OR}{1000}} \times f.$$

In the triangle *JOI*, the angle ω in mils equals $IJ \div \frac{OJ}{1000}$ multiplied by some obliquity factor which we may call *f'*. Therefore we have $\omega = \frac{IJ}{\frac{OJ}{1000}} \times f'$.

The two obliquity factors *f* and *f'* are very nearly equal; and, because the error in deflection is usually very small, we may assume that *OR* practically equals *OJ*. Dividing the members of one equation by the corresponding members of the other, we have

$$\frac{\alpha}{\omega} = \frac{RR_1 \times f}{OR} \times \frac{OJ}{IJ \times f'}, \text{ or if } f = f' \text{ and } OR = OJ, \text{ we have}$$

$$\frac{\alpha}{\omega} = \frac{RR_1}{IJ} \text{ or } RR' = \frac{F}{\omega} \times \alpha.$$

The correction coefficient to get on the line is therefore the ratio $\frac{F}{\omega}$ when a range change is to be used.

As above explained, ϕ is the corresponding change in deflection to be made to keep shots on *OT* line when range is changed one fork, *F*. Therefor the ratio $\frac{\phi}{F}$ expresses the relation between range and deflection changes to stay on the line.

Observer displacement.

The angle between the line observer-target and the line base piece-target is the observer displacement, and it is known as the angle "*i*".

PRINCIPLES OF ADJUSTMENT. OPEN WARFARE.

Preparation Fire.

Preparation fire is the process of bringing the burst on the observing line. There are two methods by which this can be accomplished; by either deflection or range changes. If the observer displacement is 300 mils, or less, preparation fire is usually conducted by deflection changes. Whenever the displacement is greater than 300 mils, range changes are used.

By deflection changes. The observer displacement is less than 300 mils. The officer conducting the fire in open warfare usually has data only roughly estimated; and, in consequence, the first center may be very far off in deflection or range, or both. If this be the case, the elements of the data which are most probably in error, must be corrected, whether range or deflection changes are subsequently to be used, and the center brought within a reasonable distance of the target, before preparation fire is begun. In Figure 8, assume that this has been done, and that the mean of two bursts

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fired with the same elevation has been observed at X_1, and that the deviation of this mean is measured as 20 mils.

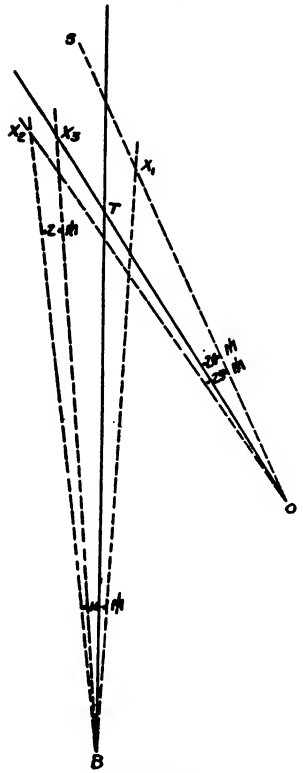

Figure 8.

The battery commander orders for example, "Left 10" (estimated). The next center is observed at X^2 and is measured as 5 mils of the observing line. These two centers are, therefore, 25 mils apart, as seen from O. The change in the location of the center was caused, primarily, by a deflection change of 10 mils at the battery, and the battery commander is therefore able to make use, in future changes, of this relation between the observed change, 25, and the actual change, 10.

The second center is 5 mils from the observing line. Knowing the above relation, the center may be brought on the line, say at X_3, by the command, "Right 2", since the measured deviation, 5, multiplied by 10/25, or 2/5, is equal to 2.

The relation thus obtained between the angle set off at the battery and that measured at O between centers of two series of shots fired with the same elevation but with different deflections, is not always exact. The battery commander should discard any relation which is not giving him good results, and should compute a new one. After a round is observed on the observing line, or in the observing sector, preparation fire is finished. This relation is the ratio to get on the line by deflection change and is expressed by $\frac{\Phi}{\omega}$ (Explained above).

Range changes. The observer displacement is greater than 300 mils. The center having been brought to X_1, in Figure 8, as explained in the case above, the battery commander measures the deviation as 20 mils right. In order to obtain a round on the observing line, he must decrease the range. Suppose he decreases the range 100 yards and the center appears where the line BX_1 crosses OX_2, the observed deviation being 5 mils left. A range change of 100 yards has caused an observed deviation of the center of 25 mils. Therefore, one mil measured at O corresponds to 4 yards in range, and the second center would, theoretically, be brought on the observing line by increasing the range 20 yards. On account of the dispersion in range, the observed deviations of centers are not exact, and the relation of mils to yards will be more or less false. The battery commander should discard the relation when it proves unsatisfactory and should compute a new one from his record, taking the average of the preceding relations. Preparation fire is completed when a round is observed on the observing line.

This relation is the ratio to get on the line by range changes and is expressed by $\frac{F}{\omega}$. (Explained above).

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Trial Fire.

A round having been brought on the observing line, trial fire is the next step in adjustment. The object of trial fire is to bracket the target in range and deflection by moving the center of the 2 rounds up or down the observing line. In Figure 9 it is quite apparent that, in order to move the center S to S_3, a change in range together with a corresponding change in deflection must be made. To explain, suppose that the first center on the line occurred at S and was observed short, and that the battery commander increased the range by an appropriate amount, but failed to change the deflection. The next center would be in the same plane of fire but off the observing line at S_1. The battery commander could measure the deviation of this center, multiply it by the ratio $\frac{\Phi}{\omega}$ he used in preparation fire and bring his bursts to the left. Say the measured deviation is 25 mils. The ratio used above was 2/5, and since 25×2/5=10, the command would be "Left 10". This gives a center, say, at S_2, the deviation of which is measured and reduced as was the first, with a resulting command of "Left 3". Suppose this gives a round on the line at S_3 which is observed over. Now, for the elevation bracket between S and S_3, the battery commander has a corresponding lateral bracket of 13 mils. When the elevation bracket is of one fork, the corresponding lateral bracket is called the lateral fork.

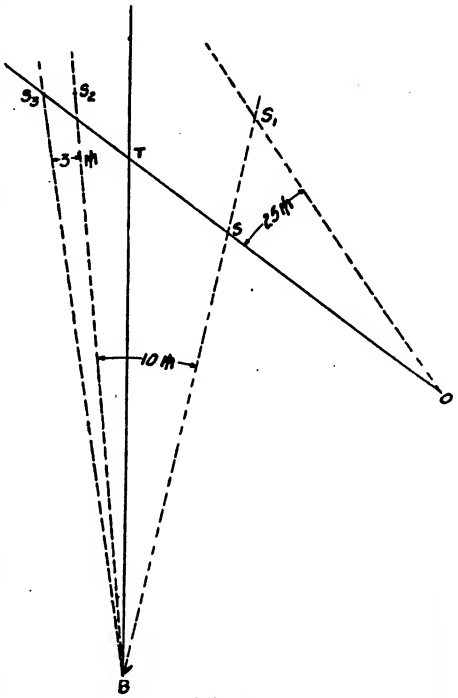

Figure 9.

As will be noted, the above is simply an explanation of moving the bursts along the observing line. Practically, this process is not carried out step by step. A burst having appeared on the line at S, the battery commander should never increase the range without ordering, at the same time, an appropriate deflection change. He would estimate the lateral shift corresponding to the range shift used and secure his second center as near the line as possible, with a fair chance of obtaining this second center on the line or at least in the observing sector. If, after this second series of two rounds, a burst is not observable on line or in the observing sector, the battery commander should bring one on the line by moving the center in the same manner employed in preparation fire. It is almost an invariable rule: that the same process of moving a center on the line in preparation fire must be used, also, during trial fire, whenever it is necessary to move a center back to the line. (Application of ratio $\frac{F}{\omega}$ or $\frac{\Phi}{\omega}$, depending on method used to get on line).

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The process of ranging along the observing line is continued until a verified range bracket of one fork, or less, is obtained. A study of the record, bearing in mind the principles already laid down, greatly facilitates the verification. On account of the fact that dispersion in direction is relatively small, a verification of the lateral bracket is not necessary.

One observation is sufficient basis for a range change, but if the center of the two rounds is more than 3 mils off the observing line, this displacement must be taken into consideration in making the next range or deflection change, depending upon whether the center was moved by a range or a deflection change in the first place.

The ratio used to stay on the line is the relation between corresponding range and deflection changes expressed by $\frac{\phi}{F}$ or $\frac{F}{\phi}$. This factor is distinct and has a separate function from $\frac{F}{\omega}$ and $\frac{\phi}{\omega}$, previously explained, and must not be confused with them.

A lateral shift of more than 16 mils is never made when one or more of the following conditions exist:

When there is danger to friendly troops;

When it is known that the deflection is nearly correct; (accurate map data).

When it is difficult to shift the trails.

When the lateral shift is limited by the above conditions, the elevation change is proportionately altered.

If, in obtaining a range bracket of one fork, the lateral fork exceeds 16 mils, both forks are reduced by halves or quarters until the lateral fork is 16 mils, or less.

Improvement Fire.

The elevation and lateral brackets having been obtained as described above, improvement fire is started at the mean of these two brackets.

Improvement fire will always be undertaken at the middle of a verified range bracket of one fork (100 yards with American matériel) or less, when the corresponding deflection bracket is 16m or less, and these brackets have been obtained by actual firing. The 12 rounds of the improvement series will be fired in groups of 3 rounds each, the first group at the middle of the range and deflection brackets, and subsequent groups at deflections determined by observations.

A number of line shorts and overs will usually be obtained in improvement fire and every effort will be made to better the deflection thru improvement fire and fire for effect. If the deflection is adjusted (target shot or otherwise) and the first or second groups of 3 rounds has yielded both shorts and overs, the remaining shots of the improvement series may be fired in a single group. Range changes in improvement fire are made on the same principles as in axial observation.

The foregoing discussion contains the general principles of adjustment with lateral observation, but it does not attempt to go into the many special cases that accur. There are numerous cases of this kind, but a strict application of the principles will always clear them; and there will be no difficulty if the rules of observation and interpretation are thoroughly understood.

In the discussion above, the battery commander has moved his bursts

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by estimations, or by applying some relation given him by his guns. These relations and estimations can be approximated whenever data can be secured; and they can be made exact by the use of exact data. An approximation can be made when the battery commander is able to measure or estimate the different elements of this data, and the closeness of the approximation will depend upon the degree of accuracy of the data. The following deals with the case where the battery commander has a good approximation of the data, but not with the case where the exactness of the battle map is possible. Mathematical discussion of the points mentioned below may be found in the appendix to this pamphlet.

If the tables of ϕ and ω are available they may and should be used. The tables themselves are accurate and the results will depend for their accuracy on the accuracy with which the range, R, distance observer-target r, and observing angle, i are known. If not accurate, the correction coefficients $\frac{\phi}{F}$ and $\frac{F}{\omega}$ or $\frac{\phi}{\omega}$ must be corrected during firing. If the tables are not at hand the correction coefficients must be determined by firing, but an idea of the changes in deflection to correspond to certain range changes may be obtained from the following:

Observing Angle	Get on Line by	Range Bound	Deflection Bound
100—200	Deflection changes	4 forks	16 mils
200—300	do	do	32 mils
300—800	Range changes	2 forks	32 mils
800—1300	do	1 fork	32 mils

These are rough approximate solutions of the equation $\frac{\phi}{F}=\frac{Tan\ i \times 1000}{R}$, ϕ in mils, F and R in yards or any other unit of distance, provided the same unit is used for both.

When the battery commander is in such a position as will enable him to measure or estimate his data with some accuracy, (referring to Fig. 15, page 33) he obtains the values:

$BT=R$=range in meters.

$OT=r$=observing distance in meters.

i=observer displacement in mils.

Now let:

$F=SY$=range change necessary to bring the center, S, to the observing line.

ω=observed deviation of any center.

ϕ=deflection change to be made at the battery to place or to keep a center on the observing line.

Take the case where the observer displacement is less than 300 mils; the center is, therefore, to be moved by deflection changes. Any observed deviation of a center must be reduced to get the corresponding deflection change to move this center to the observing line. To accomplish this reduction the observed deviation is multiplied by the relation $\frac{\phi}{\omega}$. This relation may be taken equal to r/R, and can, therefore, be calculated in advance.

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If the center is to be brought to the line by range changes (angle greater than 300 mils), the observed deviation of the center in mils is multiplied by the relation F/ω, and the result is the range change in meters. This relation, F/ω, may therefore, be calculated in advance.

The correct mathematical formula is $\frac{F}{\omega} = \frac{r}{1000 \times Sin\ i}$ or $\frac{F}{\omega} = r$ (in kilometers or thousands of yards) $\times f$, where F is in meters or yards and f is a factor given by the following table:

Observing Angle in Mils	1600 - 1200	1000	800	600	400	200
factor f	1.0	1.2	1.4	1.8	2.4	3.5

Thus for r=3000 meters.
i= 550 mils.

A burst center is observed 15 mils from OT line. Range change F to bring burst on line is given by:

$$F=15\times3\times1.8=81 \text{ meters.}$$

with quadrant laying this change may be made nearly exactly. With American matériel the nearest multiple of 25, or 75 would be used.

It will be noted that F is used to represent both the value of a fork and the range change made to get on the line or to keep on the line.

These relations, $\frac{\phi}{\omega}$ and $\frac{F}{\omega}$, have been called "correction coefficients." In the above two cases, they should not be expected to yield exact results. The battery commander should continually improve these coefficients by comparing them with those calculated from the record, as explained in the discussion above.

A round having been brought on the line, no matter by what method, it is kept there by a range change and a corresponding deflection shift. The deflection shift for the chosen range change can be calculated in advance by the ratio $\frac{\phi}{F}$ in which F is known and ϕ is taken from tables. In case no tables are available use the arbitrary table of corresponding range and deflection changes given above. (Page 20).

Use of Tables of ϕ and ω.

When the ϕ and ω tables are available, they should be used instead of the above rough method.

To illustrate, suppose
R=4000 meters.
r=2000 meters.
i= 500 mils to right of plane of fire.
From tables find
ϕ= 13.
ω= 24.
F= 100 yards (American matériel).

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The battery commander should before firing, perform the following calculations:

$$\frac{\phi}{\omega} = \frac{13}{24} = .542$$

$$\frac{F}{\omega} = \frac{100}{24} = 4.17$$

$$\frac{\phi}{F} = \frac{13}{100} = .13$$

The center having been brought to the observing line by applying the proper coefficient, and a round having been observed short, the battery commander decides to make a 200-meter range change.

$$\frac{\phi}{F} = .13$$

$$F = 200$$

$$\therefore \phi = .13 \times 200 = 26 \text{ mils for the 200-meter range bound; and the battery commander shifts left 26, and increases the range 200 meters.}$$

In most cases this does not give bursts on the observing line. The battery commander then moves the new center to the line by the same process he used in preparation fire, and makes the necessary alteration in the range or deflection bracket necessitated by this correction.

When ϕ and ω are determined from the tables or from a map, to use the ratios $\frac{F}{\omega}$ and $\frac{\phi}{F}$, F may be in any unit, and the range changes resulting will be given in terms of meters, yards, twentieths or degrees and minutes according as F was taken in one or another of those units.

Summary.

In lateral observation memorize the following rules:

1st. Get on line by $\frac{\phi}{\omega}$ or $\frac{F}{\omega}$ depending on whether you are using deflection or range changes.

2nd. Stay on line by $\frac{\phi}{F}$ in both cases.

3rd. Determine these coefficients by plotting, from your tables, with logs or slide rule, or by estimation.

4th. Don't hesitate to change the coefficients as a result of firing except when you have accurate map data and know you have made no mistake. In that case do not change.

5th. Sense rights and lefts as overs and shorts when you have split a deflection bracket of 16 μ or less.

6th. Use the rules of axial observation in so far as they apply.

7th. In cases not covered by the above use common sense and fire according to your judgment.

HINTS ON TERRESTRIAL OBSERVATION.

Lateral.

In all firing, if definite information is obtained from firing this information will be acted upon, even if it contradicts authorized assumptions of observation. Example: firing at the center of a 16μ deflection bracket. observer on the left of line GT, rights are taken as shorts, lefts as overs. A burst appears to the right of the observing line, but is clearly sensible on target or on terrain as over. This round must be taken as over.

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If the mean observed deviation of two rounds fired at a given elevation is not more than 3m from the observing line the center of impact of these rounds may be considered in practice as being on the observing line. If no sensings for deflections have been obtained, the range must, of course be repeated.

Critical elevations; both the long and the short limits of the bracket being sought in trial fire.

Critical deflections; when a deflection bracket of 16m or less, is split and the assumption made that the plane of fire passes near the target; both the right and the left limits of the bracket split are critical deflections.

All assumed elevations and deflections if they become critical, must be established by actual firing.

Whenever a deflection bracket of 16m or less has been obtained, this bracket will be split and the assumption made that the plane of fire then passes near the target. This rule applies regardless of the number of forks contained between the limiting elevations of the deflection bracket established.

Rounds sensible on the observing line by reason of the force of explosion are taken (in all cases) for elevation as though they were line observations.

Rounds sensible on the observing line by reason of the force of explosion are (in all cases) taken for direction as though they were line observations, except when firing at the center of a deflection bracket of 4m or less. In this case to warrant a deflection change, line observations or better (see page 12, 2nd par.) must be obtained.

If improvement fire is undertaken without changing the elevation (i. e. as result of verified contradictions in trial fire) all rounds fired continuously at the trial elevation may be counted in as observations in improvement fire. Thus if three rounds may be so counted it is necessary to obtain only nine additional observations in improvement fire.

N. B: This rule applies even though deflections changes are involved while firing at the same elevation, and it also applies in axial observation.

In trial fire a target hit counts two observations; as one short and one over.

In improvement fire a target hit counts as one observation only, ½ short ½ over; but necessitates the doubling of all observations included in improvement fire. Example: 5—, 6+, 1 target=10—, 12+, 1—, 1+=11—, 13+.

In bringing in the other guns of a battery after the directing piece has been adjusted, it may be assumed that the planes of fire are near the target, if a parallel or converged sheaf has been well established by previous firing. When this is the case observations to the right and left of the *OT* line will be taken at once as shorts and overs in the usual manner. If observation yields deflection shorts or overs, changes of 4 mils in the appropriate sense will be made until the target is bracketed. Deflection adjustment will then be completed in the usual way.

Where map data is used, the maximum deflection shift is 16 mils. If necessary, the corresponding range bound will be reduced accordingly. This holds true whether corrections of the moment have been applied or not.

Percussion Bracket Adjustment. (Lateral Observation).

Up to this point it has been assumed that a precision adjustment was desired. A percussion bracket adjustment by means of lateral observation must also be discussed.

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Let us suppose that it is desired to neutralize a certain target by either percussion or time fire, and that there is some point in the target suitable as an adjusting point. The adjustment is made with the piece in the sector of which the adjusting point is located, the other three pieces being careful to follow the changes of data ordered in the adjustment. Preparation fire and trial fire are completed to the point where a range bracket, not necessarily verified, depending upon the nature of the target, and its corresponding lateral bracket, are obtained in the same manner as in percussion precision. A change is then made to the mean deflection and mean elevation of these brackets, and the sheaf is altered, on the adjusting piece, to fit the target. With this data, regulating salvos or volleys are fired in order to adjust the height of burst, if necessary, and to see that the sheaf, as a whole, fits the target. No attempt should be made to adjust the distribution because dispersion in range makes this hopeless from a lateral station.

If no definite information is to be had as to the position of the target within the deflection bracket obtained the regulating salvo or volley should be fired at the center of the deflection bracket and the corresponding elevation in the hope that the deflection bracket may be narrowed. If, however, it is known approximately where the target lies within the deflection bracket, the regulating salvo or volley will be fired at the deflection corresponding to the target's position.

When the width of the target cannot definitely be determined, fire for effect is delivered over the entire front included within the deflection bracket obtained, each gun being assigned 1/4 of the bracket.

When the width of the target can be determined with respect to the deflection bracket, fire for effect is delivered over a front that corresponds to the actual width of the target, regardless of the size of the deflection bracket obtained in adjustment.

This entire process is based on the assumption that the guns of the battery are calibrated and that the battery commander knows how the sheaf is formed with respect to the adjusting piece. If neither of these conditions are fulfilled, each piece must be adjusted as prescribed for the adjusting piece.

The entire range bracket in fire for effect is covered as explained under Axial Observation.

3. FLANK OBSERVATION.

Flank observation exists when the observing angle is greater than 1600 mils. In such case an error in range appears, to the observer, to the right or left of the target and can be measured; while an error in direction appears merely short of or beyond the target, if in the observing sector. The determination of the elevation corresponding to the target is easy, and this elevation, owing to the size of the observing angle, will remain very nearly the same all along the observing line for the successive changes in deflection.

When the distance OT is known or can be estimated, the number of mils deviation of the burst center can be measured, and the amount short or over in yards (or meters) of these centers can be calculated and the succeeding ranges to be used, determined. In this way a change as small as ½ fork or as great as 4 or 6 forks might be made from the initial salvo. After a range bracket of 1 fork or less has been obtained, further ranges used in the endeavor to get shots on the line and adjust the deflection

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will ordinairly be determined upon by splitting the range bracket already obtained.

The deflection is then adjusted in the usual way by obtaining deflection shorts and deflection overs. Where a map is used deflection shifts should never exceed 16 mils at a time; where estimated data are used, this shift will be 32 mils except when there is danger of hitting friendly troops. This is an ever present danger in flank observation and must always be carefully considered.

The principles applying to this fire are the same as in lateral observation.

4. COMBINED OBSERVATION.

To prevent an undue expenditure of ammunition, combined observation should be resorted to as often as possible. It is carried out by means of:

(a) an axial observer who adjusts the fire in direction; and,

(b) a lateral or flank observer who adjusts the fire for range.

Axial Observer.

This observer should be placed as near as possible to the battery position in order to remain approximately in the plane of fire for the different targets in the sector allotted to the battery. He need not see the target completely but need only know accurately its direction. Such would be the case when he could see only the top of the target projecting above a crest or mask. Such also would be the case where he is able, after drawing on a battle map the line gun-target, to identify on the map some object on the terrain close to the line which can be seen from the axial observer's station. Such an object might be a farm, tree, church steeple, etc., which could be used as a reference point in measuring the displacement of the rounds.

From the reports made by the axial observer, the battery commander may readily adjust the direction of fire.

Lateral Observer.

He may be placed at any point as long as he can get a good view of the target. After the direction is approximately adjusted, his work is simple. If he is on the right of the plane of fire all the rounds seen to the right of the observing line are over and those to the left are short. The contrary happens if the observer is on the left. Changes in range before a rough adjustment of the deflection should be made only when clearly indicated.

Combined observation can be used with excellent results in the following cases:

1st. In adjusting time fire on the first line, the position of the bursts being observable whatever their height may be. This is especially useful in adjusting the fire of time shell and shrapnel, the height of burst for effect being raised or lowered after adjustment by means of a change of site which changes the elevation without changing the burst range.

2nd. Adjusting percussion shell which give only a little smoke.

3rd. Precision adjustment on the first lines.

4th. In night firing, and in foggy weather when on account of the mist, it is sometimes possible to observe the tops of trees or buildings from a distance, but not possible to observe easily objects close to the ground.

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5. BILATERAL OBSERVATION.

When combined observation is impossible, bilateral observation should be resorted to where circumstances permit. It is particularly suitable for adjusting fire on targets that have no relief, but do have one point clearly observable from both stations, which may be taken as the adjusting point. The method is valuable only if the battery commander can make sure that the same adjusting point is being used by each observer.

Observers are called "right" or "left" according to their positions in regard to the plane of fire. They may both be on the same side of the plane of fire, though preferably one should be on each side of it. Each observer should follow carefully, in observing and reporting rounds, the rules set forth in the first part of this pamphlet as applicable to all cases of terrestrial observation.

There are two methods of finding the position of the bursts by means of bilateral observation:

(a) The graphical method;
(b) The index method.

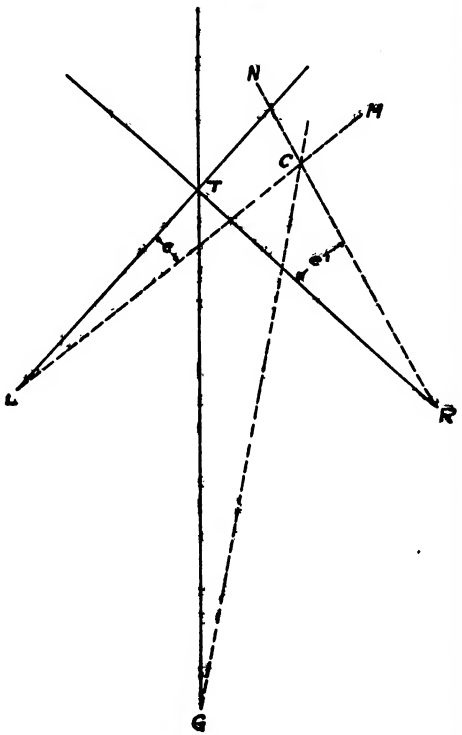

Figure 10.

Graphical Method.

This method is used when the exact coordinates of the gun, of the target and of each of the two observing stations are known and can be accurately plotted on the map or plane table. As shown in Figure 10, the displacement measured by each observer is marked on the plane table either on the right or on the left side of the observing lines *RT* and *LT* as the angles *c'* and *c*. By drawing the lines *ML* and *RN* limiting those angles, it will be seen that they meet at point C which is the point of fall of the projectile.

Connect C and G with a line. The measurement of the angle *CGT* will give the deflection correction necessary to bring the next round on the line gun-target, and by comparing the distances *GC* and *GT*, the proper correction in elevation to bring the next round on the target can be calculated very readily.

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Practically this method is carried out in the following way: As the usual scale of the battle map, 1/20,000 or 1/10,000, is not large enough to allow accurate measurement, we enlarge the zone of the target to a scale such as 1/5,000 or 1/2,000.

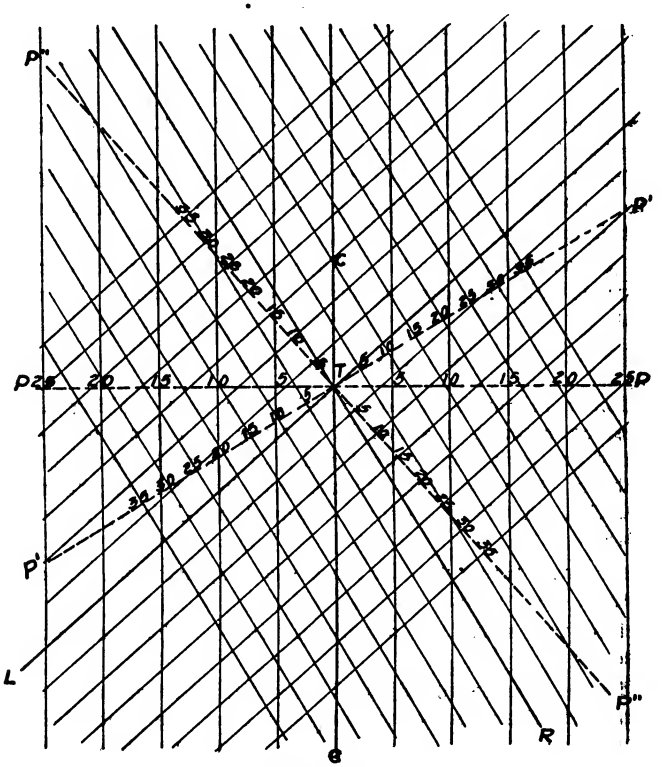

Figure 11.

Assume any point near the center of the sheet as the target. It is not necessary to plot the positions of the gun and of the observation stations; but from *T* merely draw lines in the direction of these points (as shown in Figure 11): target-gun (*TG*), target-right observer (*TR*), and target-left observer (*TL*). Also from *T* draw the lines *TP*, *TP'* and *TP"* perpendicular to the above lines respectively. Each of these perpendiculars is then divided into spaces corresponding to 5 mils as seen from the gun, the right observer, and the left observer respectively.

To illustrate, assume that the distance gun-target is 4000 meters. The angle of 5 mils as seen from the gun, corresponds to a length of twenty meters on the line *TP*. At a scale of 1/2,000, one millimeter on the map represents 2000 millimeters or 2 meters on the ground; therefore to represent 20 meters, the divisions along *TP* have to be 10 millimeters apart. The same principle applies when working with yards instead of meters.

Values of the divisions along the lines *TP'* and *TP"* are found in a similar manner.

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Because of the large scale of the drawing, it may be assumed that the lines from the gun, the right observer, and the left observer to the points of division on the lines *TP*, *TP'* and *TP"* respectively form three groups of parallel lines. Several lines of each group should be drawn. In order that the range correction may be rapidly determined, the line *GT* may be graduated in convenient units of meters, yards, etc.

Adjustment in Direction.

If the right observer announces "10 right" and the left observer "15 left" the intersection of the line numbered 10 mils to the right of *RT* and the line marked 15 mils to the left of *TL* will give the point of fall *C*. We have only to read the angular distance to the line *GT* and correct the deflection by this quantity.

If the correction is smaller than four probable errors in direction a change is made only if a certain number of rounds show the necessity of this correction.

Adjustment in Range.

Adjustment in range is accomplished by first making a correction equal to the error in range as shown by plotting the fall of the round. After that, changes of one fork may be used and trial fire and fire for improvement proceeded with in the usual way, or use may be made of the method laid down in Sec. 236, "Artillery Firing", Army War College, February, 1918. It is as follows:

"Correct each round by the observed displacement, divided by the serial number of the round.

"The first two shots are numbered "one"[1]. Those not observed are not numbered.

"The fire is considered adjusted when three times in succession the range and the deflection corrections are less than one probable error.[2]

"This method of adjustment should be used only when the rate of fire is sufficiently rapid to insure the series being fired under the same atmospheric conditions.

"Moreover, the rule, divide the displacement by the shot number, is only applicable up to a limited number, six for example. If after seven shots (the first included), the adjustment has not been secured, a new series of numbers should be begun, applying the rule as before.

When time is lacking to prepare the drawings this method may be carried out in the following way:

Three fans graduated in 5 mil divisions are prepared on transparent paper or celluloid. One of these, the gun fan, is also graduated in ranges. The gun fan is placed on the drawing with its center at the gun. On the top of it are placed the other two fans with their centers at the observation stations. All three fans are so placed that their zero lines will pass through

"(1). The adjustment properly speaking begins only with the second shot. The first shot simply gives measurements by which those following can be placed close to the objective, where the displacements can be accurately measured.

"(2). It is a question of the correction and not of the displacement on which it is based."

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the target. By the aid of these fans, shots may be plotted in a manner similar to that above (see Figure 12).

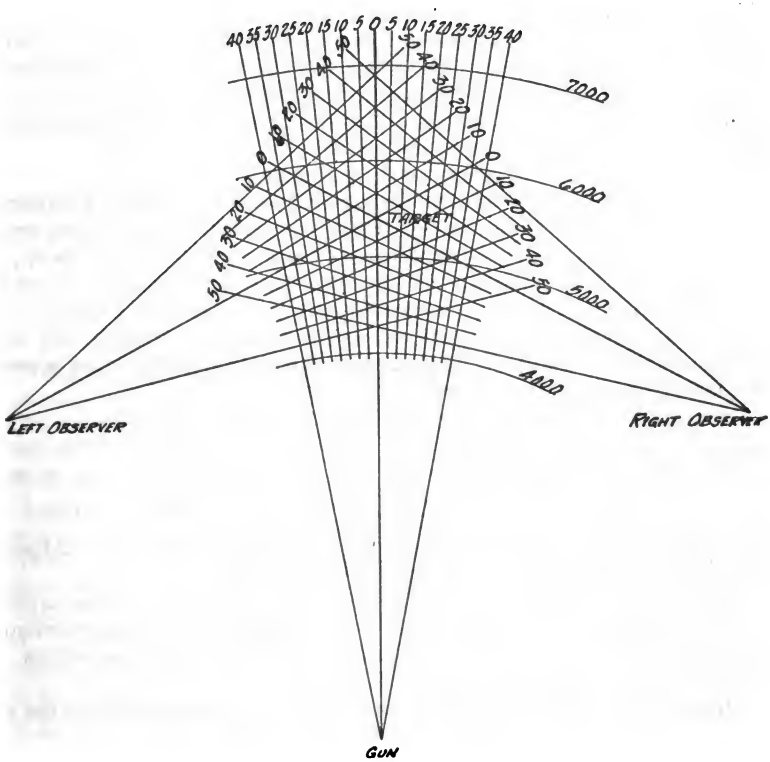

Figure 12.

Index Method.

This method is applicable where the location of the observation stations of the battery, or of the target is not accurately known. It can therefore be used in open warfare and in all cases where the locations of the guns, of the target and of the observing station are only approximate. The index method does not yield as precise results as does the graphical method, and should not be used to obtain a closer adjustment than a verified bracket of one fork. This bracket can then be covered by zone fire; or, if precision fire is desired, the adjusted elevation can be obtained by using the two stations as if they were two lateral observers. The two observers are respectively called "right" or "left" according to their position with relation to the line gun-target. They observe and report to the battery commander as in other cases of lateral observation.

The battery commander gives to the figure for the displacement of the shot, as measured by each observer, the sign + when it is on the same side of the observer-target line as the observer is of the gun-target line. Thus if the right observer reports "10 right", the battery commander uses

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the sign + before the number "10". If the left observer reports "10 left" the battery commander also uses the sign + before the number "10". If however, the right observer should report "15 left" the battery commander would place the sign — before the number "15".

The battery commander should estimate the distances from each observation station to the target and divide each of these by the distance gun-target. This will give the correction coefficient for each observation station. Each number received as above from the observers should then be multiplied by the correction coefficient of its respective observation station.

Adjustment in Range.

The "index" of a round is the *algebraic sum* of the two numbers reported by the observers after the coefficients of reduction have been applied. A round is "over" if the index is greater than zero, that is, if it is +, and "short" if the index is smaller than zero, that is, —. A round is at the same distance from the gun as the target when its index is equal to zero. When the index of a round is very small, the round must be taken as doubtful, but near the range of the target. The round is doubtful when a sensing is obtained from only one observer.

To determine the first range bound, if the deflection is approximately correct, the observed deviation as seen by one observer (the one with greatest observing angle i preferred) may be converted to yards or meters by ratio $a \times \frac{r}{1000} \times f$ where f is the ordinary obliquity factor. The range is then changed by the nearest whole fork corresponding. After that change by one fork; bracket and split in the usual way.

The usual procedure of passing to improvement fire at the middle of a verified bracket of one fork or less, is then followed. In improvement fire disregard indices, and sense overs and shorts as in lateral observation. Only one or both observing stations may be used.

The displacement of each observer should as far as possible be the same.

Adjustment in Direction.

The location of the round with regard to its direction is obtained by *subtracting algebraically* the number given by the left observer from the number given by the right observer, both numbers having first been multiplied by their respective correction coefficients, and the result divided by two. If this quotient is "plus", the round has fallen to the right of the line gun target; if "minus", the round has fallen to the left. The quotient obtained represents approximately the number of mils to the right or left that the round has fallen. The proper deflection change is therefore directly indicated to the battery commander.

HINTS ON TERRESTRIAL OBSERVATION.

Bilateral.

Bilateral observation: Adjustment of deflection. The system of adjustment by measured deviation may be employed until, (a) the correction to be made is less than four probable errors, or (b) the correction to be made is equal to or greater than a previous correction in the opposite direction. When either of these conditions develops further changes in deflection will be based only on absolute information regarding the plane of fire obtained from his respective observing line (by either observer). Such information will be followed by a change of 4 mils in the appropriate direction. This process will be continued until the deflection is adjusted, and is appropriate to both index method and that of measured deviations.

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This change of 4‰ assumes, of course, an 8‰ bracket, split, hence the indices may be abandoned and shorts and overs sensed by being right or left of the line using either observer's seasings, or both, as a check.

The index method is not at all satisfactory unless the line gun-target passes about midway between the two observing lines. In the contrary case, make an arbitrary deflection change of 8‰ instead of the 4‰ mentioned above. It should never be employed with both observers on the same side of the gun target line.

Common sense must govern at all times. Innumerable cases are constantly arising to which the ordinary rules of observation will not apply satisfactorily. In all such cases follow the reasonable course.

The geometrical demonstration of the principles of the index method of bilateral observation is as follows:

Range:

Lay off the line *GT* as shown in Figure 18. Draw a circle of any convenient radius with its circumference passing through *T* and its center on *GT*. Assume any two points on the circumference, one on each side of *GT*, as *R* and *L*. Let *R* represent the right observer and L the left observer.

Suppose a round falls at the point *E* on the circumference of the circle. Draw the lines *RT*, *LT*, *LE* (extending *LE* beyond the circumference) and *RE*. Let the angle *TRE*=*i'* and the angle *TLE*=*i*.

Since the arc *TE* is subtended by the angles *i'* and *i*, each having its vertex on the circumference of the circle, *i'*=*i*.

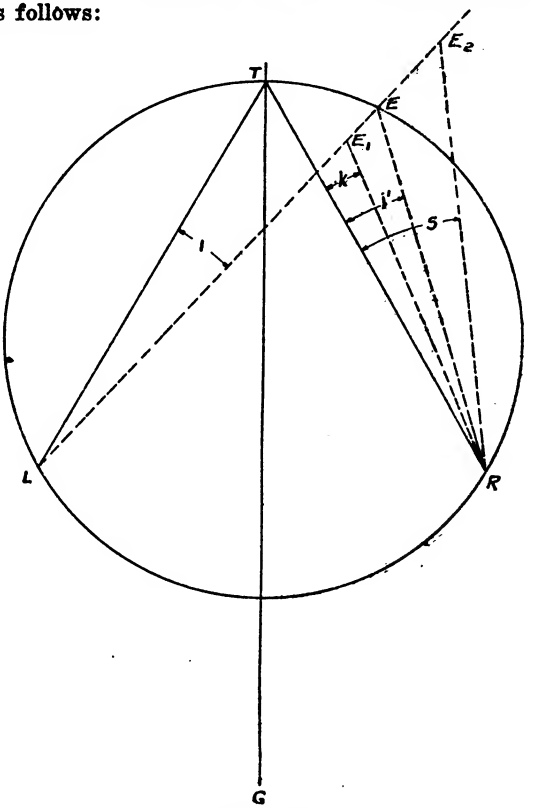

Figure 18.

Following the rule in the index method, the report to be given for the round observed at *E* by the observer at *R*, would be "right *i'*", or +*i'*. The report from the observer at *L* would be "right *i*", or —*i*'.

Therefore the index of the round at *E* would be *i'* — *i*, but *i'*=*i*, therefore the index of *E*=0. This demonstration is of course based on the assumption that, for all practical purposes, on account of the great distance in range compared to the small distance that a round should be off the target

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in deflection, the arc TE is the same as an arc drawn through T with a radius GT.

Suppose again that a round falls at E_1. It would be reported from R as "right k" (k=angle TRE_1). It would be reported from L as "i right". The index of the round would be $+k-i$, but $i=i'$, therefore by substitution the index would be $+k-i'$. From the figure it is readily seen that i' is greater than k, therefore the index of the round at E would be —, the round therefore being sensed as short.

Suppose in the third case that a round falls at E_2. It would be reported from R as "s right" (s=angle TRE_2). It would be reported from L as "i right". The index of the round would therefore be $+s-i$. But $i=i'$, therefore substituting, we have the index equal to $+s-i'$. From the figure, s is greater than i', therefore the index of the round is +, and the shot must be sensed as over.

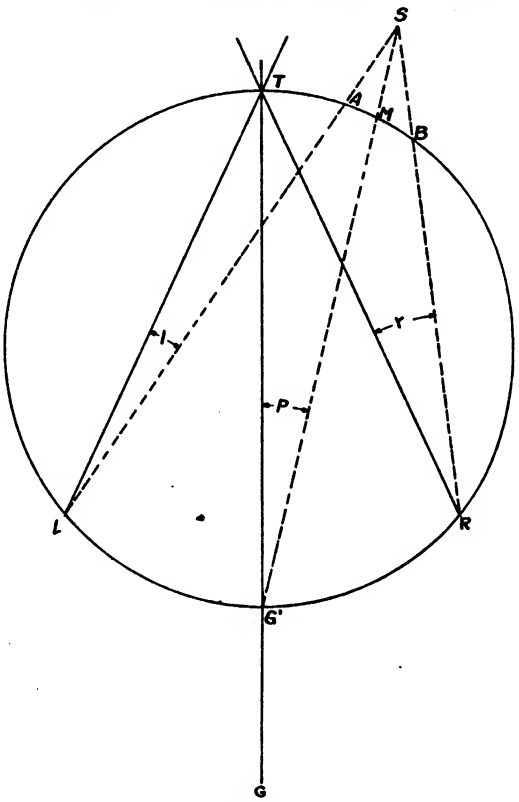

Figure 14.

Deflection:

Lay off the line GT as shown in Figure 14. Draw a circle of any convenient radius with its circumference passing through T and its center on GT. Let R and L be points on the circumference representing the right and left observing stations respectively. Mark the point of intersection of the circumference with the line GT between R and L by the letter G'. Draw RT and LT. Assume that a round falls at S. Draw the lines RS, $G'S$, and LS. Let the angle $TRS=r$, the angle $TG'S=p$ and the angle $TLS=l$. Mark the points where the lines LS, $G'S$ and RS intersect the circumference near T, by A, M, and B, respectively.

If the gun is supposed to be at approximately the same distance from the target as are R and L, for example, at G', the correction in deflection to bring the round from S to the $G'T$ line would be "Left p". The plane of fire would have shifted through the angle $MG'T$ which subtends the arc MT. The displacement of the two observers being approximately equal, the angles LSG' and RSG' will also be practically equal, since as before stated, the error in deflection is very small compared to the range. The point M may

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therefore be assumed to be at the center of the arc BA. Then, the arc $MT = \frac{\text{arc } BT + \text{arc } AT}{2} = \frac{r + l}{2}$ or $p = \frac{r + l}{2}$.

Following the rule in the index method, the round at S would be reported from R as "r right" or $+r$. The round would be reported from L as "l right" or $-l$. The deflection displacement, therefore, according to the rule, would be represented by the following formula,

$$p = \frac{+r - (-l)}{2} = \frac{r + l}{2},$$

which corresponds to the result obtained from the above demonstration of the method.

PRINCIPLES OF LATERAL OBSERVATION.

Appendix.

Let $BT = R$ = The range.

$OT = r$ = observing distance.

$SY = F$ = Range change that is necessary to bring shot S on line OT.

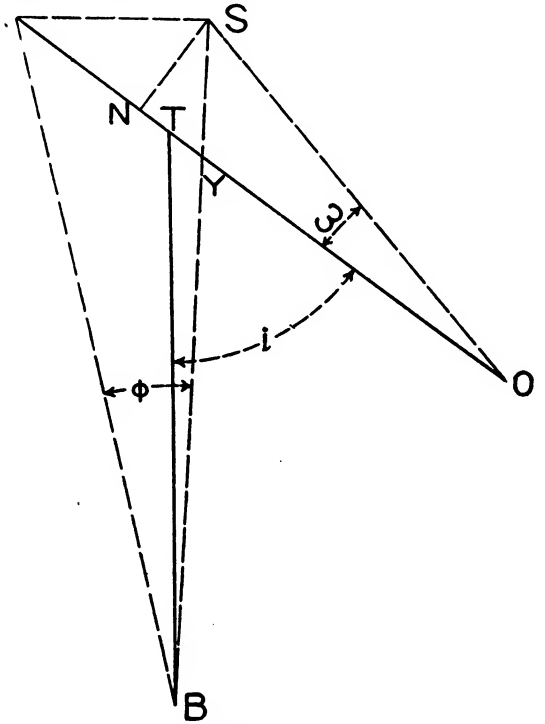

Figure 15.

SX = Lateral distance necessary to bring shot S on line OT.

ω = Observed deviation in mils.

ϕ = Deflection change to be made at the battery to place or to keep the shot on the line OT.

i = observer displacement.

Draw SN perpendicular to OX (observing line) and call it "a".

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For practical purposes it will be sufficient to make the following assumptions:

(a) That the fire is approximately correct for direction and range and consequently $B\ S$ may be considered parallel and equal to $BT=R$.

(b) That the actual distance of the burst from O is approximately equal to the observing distance $OT=r$.

(c) That the angles ϕ and ω are small.

Then, $Tan\ \omega = \frac{SN}{OT}$ approximately $= \frac{a}{r}$

For small angles $Tan\ \omega = \frac{\omega}{1000}$, therefore $\omega = \frac{1000\ a}{r}$ (1)

Since angle NSX = angle i, $\frac{SN}{SX} = cos\ i$, therefore $SX = \frac{SN}{Cos\ i} = \frac{a}{Cos\ i}$

$$Tan\ \phi = \frac{SX}{BT} \text{ approximately} = \frac{a}{R\ Cos\ i}$$

For small angles $Tan\ \phi = \frac{\phi}{1000}$, therefore $\phi = \frac{1000\ a}{R\ Cos\ i}$ (2)

Since angle SYN = angle i, $Sin\ i = \frac{SN}{SY} = \frac{a}{F}$, therefore

$$F = \frac{a}{Sin\ i} \tag{3}$$

Dividing the members of Equation 2 by the corresponding members of Equation 1, we have

$$\frac{\phi}{\omega} = \frac{r}{R\ \ Cos\ \ i} \tag{4}$$

which expresses the relation between the observed deviation, ω, and the deflection change, ϕ, to be made at the guns, to bring the next shot on the line OT by a deflection change only.

When the observer displacement is less than 400 mils cos i is approximately unity, so that when the angle of displacement is less than 400 no appreciable error is made in taking

$$\frac{\phi}{\omega} = \frac{r}{R} \tag{5}$$

Dividing the members of Equation 3 by members of Equation 1, we have

$$\frac{F}{\omega} = \frac{r}{1000\ \ Sin\ \ i} \tag{6}$$

which expresses the relation between the observed deviation, ω, and the change in range, F, to bring the next shot on the line OT by a range change only.

In order to convert this range change to a corresponding elevation change in mils, minutes or twentieths, it will be necessary to divide the factor or the result by the number of meters corresponding to an elevation change of one mil, one minute or one twentieth at the particular range. This information is given in the range tables.

Dividing members of Equation 2 by members of Equation 3, we have

$$\frac{\phi}{F} = \frac{1000\ Sin\ i}{R\ Cos\ i} = \frac{tan\ i}{R/1000} \tag{7}$$

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which expresses the relation between the change in range, F, and the corresponding change in the deflection, ϕ, to keep the next shot on the observing line OT by a simultaneous change in both range and deflection. The same result will also be obtained by dividing Equation 4 by Equation 6.

The numerical value for the factors $\frac{\phi}{\omega}$, $\frac{F}{\omega}$ and $\frac{\phi}{F}$ should, if possible, be calculated in advance. The exact values may be calculated by the equations deduced above, re-stated here.

These Are the Basic Formulas of Lateral Observation.

$$\frac{\phi}{\omega} = \frac{r}{R \, Cos \, i} \tag{4}$$

$$\frac{F}{\omega} = \frac{r}{1000 \, Sin \, i} \tag{6}$$

$$\frac{\phi}{F} = \frac{1000 \, tan \, i}{R} \tag{7}$$

Computation of Initial Map Data.

The following method of computing initial firing data without plotting is very rapid, accurate and satisfactory when co-ordinates are given.

Let (X, Y) and (X', Y') be the coordinates of any two points, and Z the azimuth from Lambert North of the line joining them.

Assume the angle N such that $Z=90°\pm N$ or $270°\pm N$ depending on the compass quadrant, containing line battery target.

Then $\tan N = \frac{Y-Y'}{X-X'}$, look up N and determine Z. (1)

The range $= R = \frac{Y-Y'}{Sin \, N}$ (2)

The angle between any two lines is equal to the difference of their azimuths.

Then the observing angle i is equal to the numerical difference of the azimuths of GT and OT lines.

The above formulas are adapted to log tables and slide rule and no attention need be paid to any signs. They are very easy of proof and can be easily demonstrated by any one interested.

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TABLE A.

TABLE OF NATURAL SINES, COSINES AND TANGENTS.

Observer Displacement in mils.	Sines	Cosines	Tangents
0	.00	1.00	.00
100	.098	.995	.0986
200	.195	.98	.199
300	.29	.956	.3
400	.38	.92	.4
500	.47	.88	.5
600	.555	.83	.669
700	.63	.77	.82
800	.707	.707	1.0
900	.77	.63	1.21
1000	.83	.556	1.49
1100	.88	.47	1.88
1200	.92	.38	2.43
1300	.956	.29	3.29
1400	.98	.195	5.02
1500	.995	.098	10.14
1600	1.0	0.0	∞

TABLE B.

CONVENIENT APPROXIMATE TABLE OF NATURAL SINES, COSINES AND TANGENTS.

Observer Displacement in mils.	Sines	Cosines	Tangents
0	.00	1.00	.0
100	.10	.99	.1
200	.20	.98	.2
300	.30	.95	.3
400	.40	.90	.4
500	.50	.85	.5
600	.60	.80	.65
700	.65	.75	.8
800	.70	.70	1.0
900	.75	.65	1.2
1000	.80	.60	1.5
1100	.85	.50	2.0
1200	.90	.40	2.5
1300	.95	.30	3.0
1400	.98	.20	5.0
1500	.99	.10	10.
1600	1.00	.00	∞

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